PATENT SPECIFICATION

678,917

Date of Application and filing Complete Specification: Sept. 18, 1948.

No. 24505/48.

Application made in Switzerland on Sept. 18, 1947.

Complete Specification Published: Sept. 10, 1952.

Index at acceptance:—Classes 69(ii), K1(b1a: d), K5e; 102(i), A3g4b(1: 2), A4v; and 122(i), B7(ax: 1).

COMPLETE SPECIFICATION

Improved Piston for Liquid-Operated Piston Engines

We, SCHWEIZERISCHE LOKOMOTIV- UND MASCHINENFABRIK, of Winterthur, Switzerland, a Joint Stock Company, incorporated under the Laws of Switzerland, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention relates to the piston of a piston engine operating as liquid-pump or motor of the type in which the piston, through its end remote from the cylinder space, is slidably supported on a surface which takes up the piston forces and may reciprocate, relative to such surface, transversely to the piston axis.

It is known in the art to definitely space the sliding surfaces of machine parts sliding upon each other, and thus to substantially reduce the friction, by recessing a pressure chamber from one of the said surfaces, which chamber is supplied through a throttling aperture with a pressure fluid.

It also is known in the art to use, in the pistons of the type described, pressure chambers supplied from the cylinder space. In such connection, however, certain difficulties arise, in that forces additional to the fluid pressure may arise on the pistons in their axial directions, such as accelerating or centrifugal forces which may be counteracted—during the pressure stroke, but not during the suction stroke—by means of the pressure chamber recessed from the piston-head sliding-face, in that during the suction stroke the pressure-fluid supply to the pressure chambers from the inside of the cylinder ceases. It is true that the pressure chamber could be kept under pressure also during the suction stroke, by means of a special pump which continuously produces pressure fluid, which arrangement, however, results in a complicated structure and additional manufacturing costs. But also when the piston engine runs idle or under a slight load, a sufficiently high pressure also no longer is available in the working space of the engine cylinder during the pressure stroke, so that the slide-face portions adjacent the outside of the chambers are pressed against each other by these additional forces, thus giving origin to increased friction and perhaps pitting or wear.

Increased friction and possibly pitting also arises on the slide-faces when the throttling aperture is clogged by impurities and the pressure chamber, therefore, is supplied inadequately or not at all.

Such difficulties may be smoothed by amply dimensioning the additional piston-head supporting-faces adjoining the pressure chambers. Such provision, however, causes a substantial increase of the piston-head diameter over that of the piston operating in the cylinder, and the mounting of the pistons becomes more difficult. Such excessive space requirement of the piston head is undesirable in piston engines which are to be designed within a minimum space. A large piston-head diameter, further, makes it difficult to provide a good abutment and a small clearance, and results in a correspondingly great inertia force, in particular when the piston operates in rotating radially arranged cylinders.

According to the present invention, a pressure chamber is provided in the end or head of the piston remote from the cylinder space and supplied with pressure liquid and additional supporting face or faces is or are provided inside the confines of said pressure chamber. As shown by tests, such provision does not in any way impair the effect of the pressure chambers of decreasing the friction. Such provision affords not only a lower weight

of the entire pistons, but also the advantage that during the pressure-period the high oil-pressure is communicated, practically instantaneously, to the entire lubricating-film on the additional supporting-faces disposed within the pressure chambers, so that the lubricating-film during the suction-period is displaced at a slower rate from the said faces. The particular feature of the piston arrangement according to the invention is formed by the provision of metallic additional supporting faces within the confines of the hydraulic pressure chamber, which faces are by no means prejudicial to the hydraulic releasing action exerted on the piston by the pressure chamber. This fact has been proved by tests that pressure oil forms an oil film between the additional supporting faces on the piston end and the piston end bearing surface of the annular engine casing, which oil film is subject to the same hydraulic pressure as the oil present in the recessed or grooved portions of the pressure chamber surrounding the said supporting faces.

When the piston engine is so operated that also the suction-space is under a certain slight pressure, e.g., 2—5 atm., there results the advantage that the additional faces upon idling also still are lubricated by pressure-oil, which only is possible at a less efficient degree when the supporting-faces are arranged outside the pressure-chambers.

Various forms of the present invention are illustrated in the accompanying drawings, in which:—

Fig. 1 shows a section through a three-cylinder radial piston engine, on the line I—I of Fig. 2, which engine comprises pistons of one or the other type shown,

Fig. 2 a side view thereof in section on the line II—II of Fig. 1,

Fig. 3 on a larger scale, a piston partly in longitudinal section,

Fig. 4 a view of the piston head of Fig. 3 in direction of the arrow A,

Fig. 5 a modification of the piston, including two adaptations of the piston head and two adaptations of the spherical segment interposed between piston-head and slide-face, and

Fig. 6 a view of the piston head of Fig. 5 in direction of the arrow B, including two modifications.

In Figs. 1 and 2, the cylinder block 3 of the engine—which may operate as pump or motor—is mounted rotatable on the control stud 2 which is rigidly secured to the casing 1, which block comprises three radially disposed cylinders. In the casing 1, further, the rotor 5 is rotatably mounted at 6 and 7 and eccentrically to the axis 2*a* of stud 2. The rotor 5 is so coupled to the cylinder block 3 through a follower 9, in form of a universal coupling, that the block 3 and the rotor 5 always rotate at the same number of revolutions. On the inside wall of the rotor 5—which may be driven through the stud shaft 10, when the engine shall operate as pump—three plane faces 11 are provided, against which the heads of the pistons 12, 13 abut. It is to be understood that the engine comprises either pistons 12 or 13. The piston 12, in particular, abuts through its slide shoe or piston head 15 directly against the appurtenant slide face 11. The pistons 13, of which only one is fully shown, abut, however, against the said faces 11 through the intermediary of an adjustable spherical segment 28.

In the rigid control stud 2, two bores 4 are provided for supplying and delivering the working-liquid, e.g. in the sense of the arrows shown in Fig. 2. The cylinders situated above the horizontal median plane of stud 2, communicate with the upper one, and the cylinders below the said plane with the lower one of the said two bores 4. The web 8 separates the engine suction-space from the pressure-space.

The structure of piston 12, in which the piston and the head 15 are integral, is shown in a larger scale in Figs. 3, 4. A shallow chamber 16 is recessed from the end face of the head 15 abutting against the face 11, and is supplied with pressure-liquid from the cylinder interior 19 through the bore 20 and the throttling-aperture 21 of the piston. In Fig. 4, the depressed portion of chamber 16 is shown hatched. The chamber is confined by the narrow annular face 23. By this means it is intended to provide fluid friction between the piston end face on the head 15 and the abutting face 11, as hereafter more clearly explained. In the chamber 16, additional supporting-faces in form of six ring sectors 24 are provided, which faces fill up the pressure-chamber 16 with the exception of the six radial grooves 25, the central recess 26 and the circular groove 29. Externally of the pressure-chamber 16 two semi-circular additional supporting-faces 14 are provided which are separated from the chamber 16 through an annular groove 17.

Pressure liquid flows from the pressure-chamber 16 through the narrow gap between the annular face 23 and the flattened face 11 into the annular groove 17 from which it may flow outwardly through the grooves 18. The chamber pressure thus cannot be propagated into the gap between the additional pressure-face 14 and the flat face 11. This perman-

ent flow of a small amount of pressure fluid forms the base for the above-mentioned fluid friction between the respective surfaces. The minimum thickness of the lubricant layer in this case is approximately 0.01 millimetres.

In order to evaluate the dimension of the area of the pressure chamber 16, the forces acting in a radial direction on the piston must be exactly determined. These forces are composed of radial forces acting on the two opposed end faces and those due to the mass of the piston. Radially directed outwards are the fluid pressure $F_k.p$ acting on the inner piston end face 22 having the area F_k, and the centrifugal force C corresponding to the mass of the piston and to the circumferential speed, occurring during normal, i.e. most usual operating condition of the engine. Fluid pressure forces are also acting in the opposite direction, from the outside inwardly. The fluid pressure prevailing in the pressure chamber 16 is designated by p_1, this value being slightly smaller than the pressure p in the cylinder 19, the area of the entire circular surface situated within the annular surface 23 being designated by F_1, and the area of this annular surface itself by F_2, the fluid pressure forces acting on these surfaces are

$$F_1 p_1 \text{ and } F_2 \frac{p_1}{2}.$$

The latter value is only approximate. It is based on the supposition that the mean value of the fluid pressure, which decreases between the inner and outer circumferential limits of the annular surface 23 from p_1 to zero, is $\frac{p_1}{2}$. Other forces, for example direct bearing reactions from the slide face 11, cannot occur since, as it is proposed to have fluid friction between the two opposed faces, there will always be a fluid layer, though extremely thin, present between these faces, which fluid layer acts as pressure transmitting means. The condition for having these radially acting forces balanced accordingly is:

$$F_1 p_k + F_2 \frac{p_1}{2} = F_k.p + C$$

or, when this equation is divided by p_1:

$$F_1 + \frac{F_2}{2} = \frac{p}{p_1}\left(F_k + \frac{C}{p}\right)$$

In the extreme condition when the flow of lubricating fluid from the cylinder space 19 to the pressure chamber and between the bearing faces ceases, and the state of fluid friction disappears, there is no longer any pressure decrease at the throttling passage 21. The fluid pressure p_1 in the pressure chamber 16 then is equal to the pressure p in the cylinder space 19. For this condition the factor $\frac{p}{p_1}$ in the last-named equation becomes 1 and the equation is as follows:

$$F_1 + \frac{F_2}{2} = F_k + \frac{C}{p}$$

In this manner, the values F_1 and F_2 of the pressure chamber 16 and the annular surface 23, respectively, with respect to the sectional area of the cylinder 19, and the values C and p upon operation, can be exactly calculated. The above equation expresses the following:

In order to attain liquid-friction in the case of full-load working-pressure, the sum of the chamber-area and half the marginal area, therefore, must exceed the sum of the piston-area and the quotient from the centrifugal or other additional force and full-load pressure. Advantageously measures are taken for attaining such ratio—at the maximum additional force C occurring within the most common working-range of the engine—even at a pressure less than the full-load pressure.

During the pressure stroke, the piston head—at the said dimensioning of the relief-chamber area—is slightly withdrawn from the face 11, ample oil flowing between the slide faces 11 and 23, 24 and, to a lesser extent, on to the face 14. During the suction stroke, the relief action in chamber 16 is no longer effective due to the lack of pressure, and the said faces 23, 24 and 14 intercept the non-compensated additional forces C. Oil then is squeezed from between the supporting faces 23, 24 and 14, and the oil layer becomes thinner until the pressure rise associated with the succeeding pressure-stroke arrives in the chamber 16. In this manner, provision is made for sufficiently lubricating the faces of the piston-head during the entire working period of the piston.

In order to ensure a sufficient lubrication of the piston-head faces also when the engine is slightly loaded and the pressure of the working liquid is low, the suction side of the piston engine advantageously also is held under a slight pressure of, e.g., 2—5 atm. by means of a special pump. When the maximum additional force C occurs only at rare intervals in operation, the faces F_1 and F_2 also can be made smaller than according to the rule set forth above.

Ledges 27 provided on the rotor 5 prevent too great a rise of the piston heads 15 from the flat faces 11, in that these ledges engage the said heads from the rear. The groove 17 may be omitted, in which case

the outside diameter of the head 15 and perhaps also that of the chamber 16 may be reduced somewhat, since then the annular face 14 also aids the action of the pressure chamber 16. In such case, however, when the chamber pressure ceases, the outside supporting-face 14 in particular is lubricated less efficiently.

The structure of the piston 13 is more fully shown in Figs. 5 and 6. Such piston structure differs from the one described above, besides the adjustable spherical segment 28 inserted between piston and slide face 11, in that the enlarged piston-head is guided on the cylinder, and in that additional supporting-faces no longer are provided outside the annular face 23. The segment 28 permits to balance small deviations of the piston axis from the direction normal to the face 11. Its spherical seat on the piston may be relieved, at least partially, by means of a pressure chamber 31. The segment 28 is traversed by a bore 30 through which the pressure chamber 16 communicates with the oil-supply bore 20—21 from the cylinder space 19.

The enlarged piston head 32 is guided, over the entire piston stroke, by means of the guide 33 rigidly secured to or integral with the cylinder block 3. In the inner dead-center position of the piston, the end face 35 of said guide is situated quite close to the slide face 11, as indicated in Fig. 5 by the dash line.

Instead of providing a continuous annular groove 29 as shown in Figs. 4 and 6, this groove may be interrupted, but in order to realise the hydraulic pressure effect on the additional supporting faces 24, groove portions at the periphery of the sector-shaped faces 24, which are supplied with pressure oil from the cylinder 19 through the radial grooves 25, should extend through at least over 80% of the full theoretical length of the arc of the sector. Under certain conditions it is of advantage to subdivide the sector-like additional supporting-faces 24 by means of further smaller grooves in order to facilitate a penetration of the pressure liquid between the said faces 24 and the faces 11.

In order to improve the bearing-capacity of the lubricating-layer of the pressure-chamber centre, the radial grooves 25 may be extended only for a certain distance toward the centre, as shown in the right-hand portion of Fig. 6. The said grooves 25 are supplied through a plurality of bores 36 from the chamber 31. The bores 36 may be interconnected through an annular groove (not shown).

The use of pistons shown in Figs. 5 and 6 permits to adopt the smallest diameter for the piston-head abutting against the slide face 11, of all the forms of invention described.

The width of the marginal portion 23 may be held rather small, as has been proved by tests, and may preferably be made less than 15% of the chamber radius.

The guide-ledges 27 provided on the rotor 5 are engaged in a recess 34 of the enlarged piston 32. The recess 34 may be provided in form of a circular turned-out groove, as shown in the lower portion of Fig. 5, or only in form of lateral milled grooves as shown in the upper portion of Fig. 5.

The pistons suitably are made of light metal with a view of diminishing the inertia forces.

If the piston head 15 in Fig. 3 is made as long as in Fig. 5, it also may be better guided by means of guide lugs 33 disposed intermediate of the ledges 27.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. In a piston for a piston engine delivering pressure-liquid or operated thereby, in which the piston is supported at its end or head remote from the cylinder space against a face which takes up the piston forces, the said piston being adapted to slide transversely of its axis on the said face, a pressure chamber is provided in the said end or head and supplied with pressure liquid, and additional piston head supporting face or faces is or are provided inside the confines of the said pressure chamber.

2. A piston as set out in Claim 1, in which a circular pressure-chamber is provided and supplied with pressure liquid from the cylinder space and an annular piston head supporting surface is provided along the periphery of the pressure chamber, the sum of the area of the pressure chamber and one half the area of said annular supporting surface being slightly greater than the sum of the inner piston end area and the ratio between the centrifugal force acting on the piston during normal operation and a cylinder pressure which is less than full load operating pressure.

3. A piston as set out in Claim 1, in which the said additional piston-head supporting-faces fill out the major portion of the said pressure chamber.

4. A piston as set out in Claims 1 and 2, in which said additional piston head supporting faces are separated from each other by radially extending grooves connected to the pressure supply by their inner ends and to an annular groove surrounding said supporting faces by their

outer ends.

5. A piston as set out in Claim 1, comprising an additional supporting-face also outside the pressure chamber, in which the additional supporting-face provided outside the pressure chamber is separated from the annular face sealing the chamber by a groove having a free drain to the outside.

6. A piston as set out in Claim 1, in which the said additional supporting-faces are provided on a spherical segment mounted in the piston-head.

7. A piston as set out in Claim 1, in which the additional supporting-faces are not interrupted by grooves in the centre of the said chamber, and the parts disposed radially outside the centre of the said chamber are supplied with pressure liquid through a plurality of individual bores.

8. A piston as set out in Claim 1, characterised in that the radial width of the annular face which closes the said pressure chamber to the outside, amounts to not more than 15% of the radius of the said chamber.

9. In a piston engine delivering pressurised liquid or being operated thereby, a piston constructed and arranged to operate substantially as described with reference to Figures 1 to 4 or 5 and 6 of the annexed drawing.

Dated this 18th day of September, 1948.
MARKS & CLERK.

Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.—1952.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

678,917 COMPLETE SPECIFICATION
1 SHEET

This drawing is a reproduction of the Original on a reduced scale.

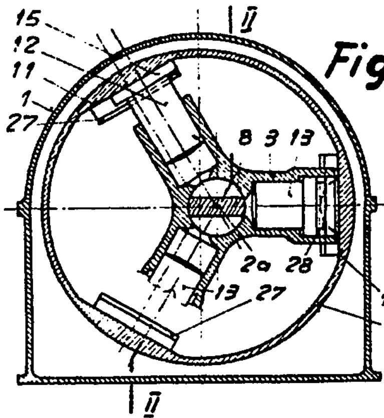

Fig. 1

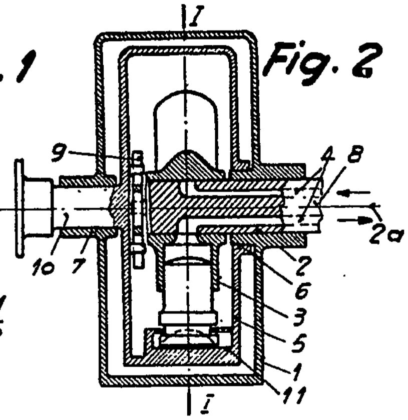

Fig. 2

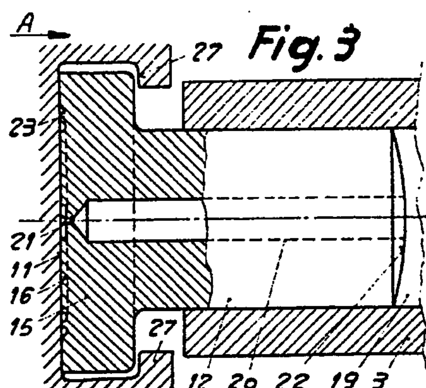

Fig. 3

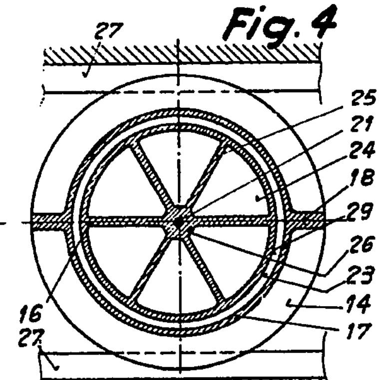

Fig. 4

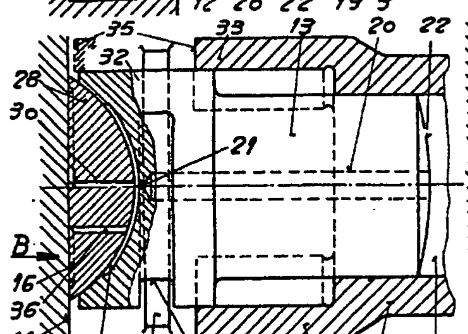

Fig. 5

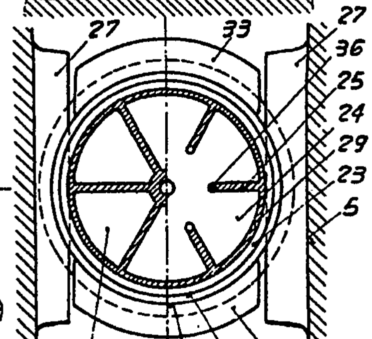

Fig. 6